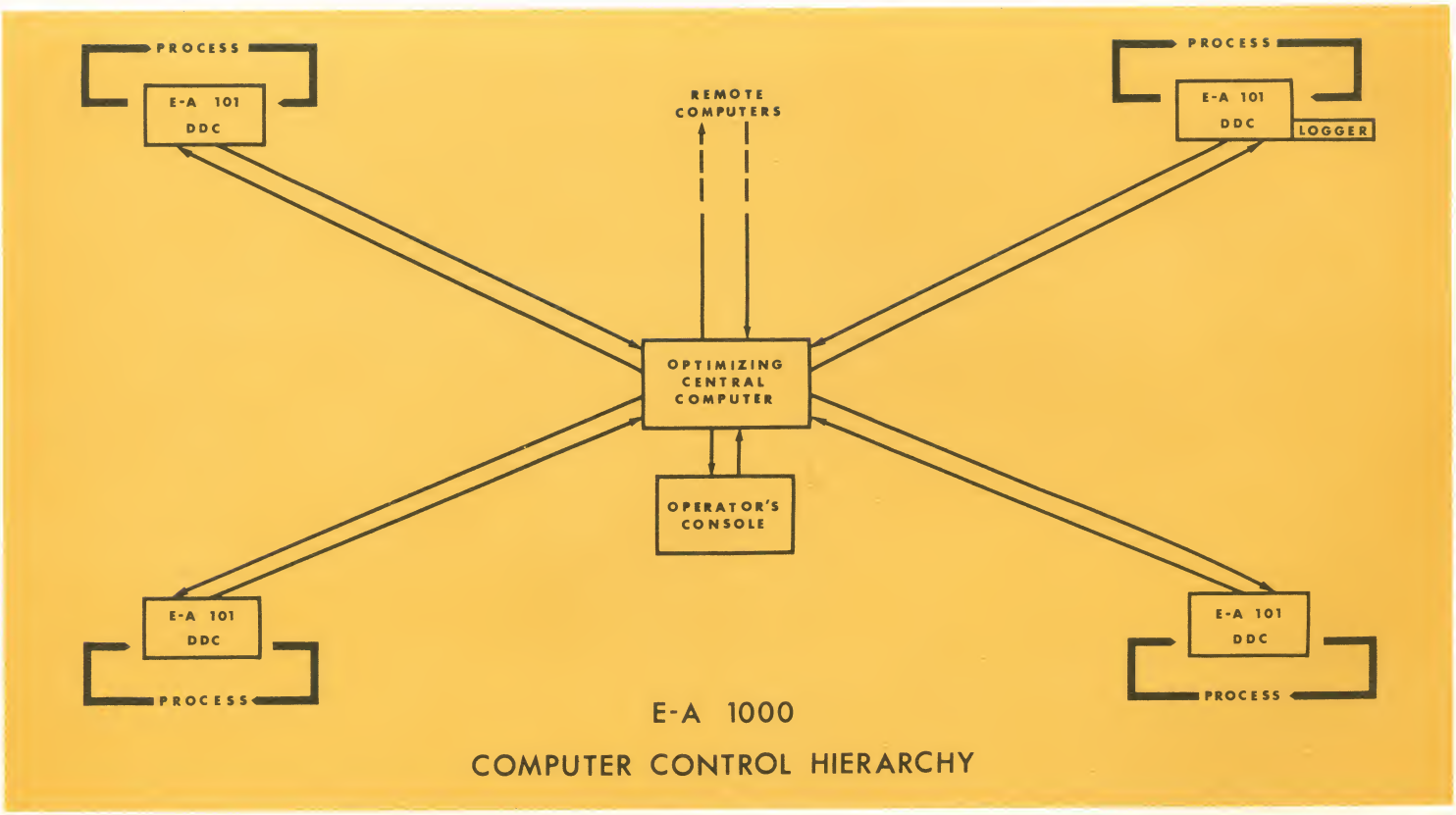
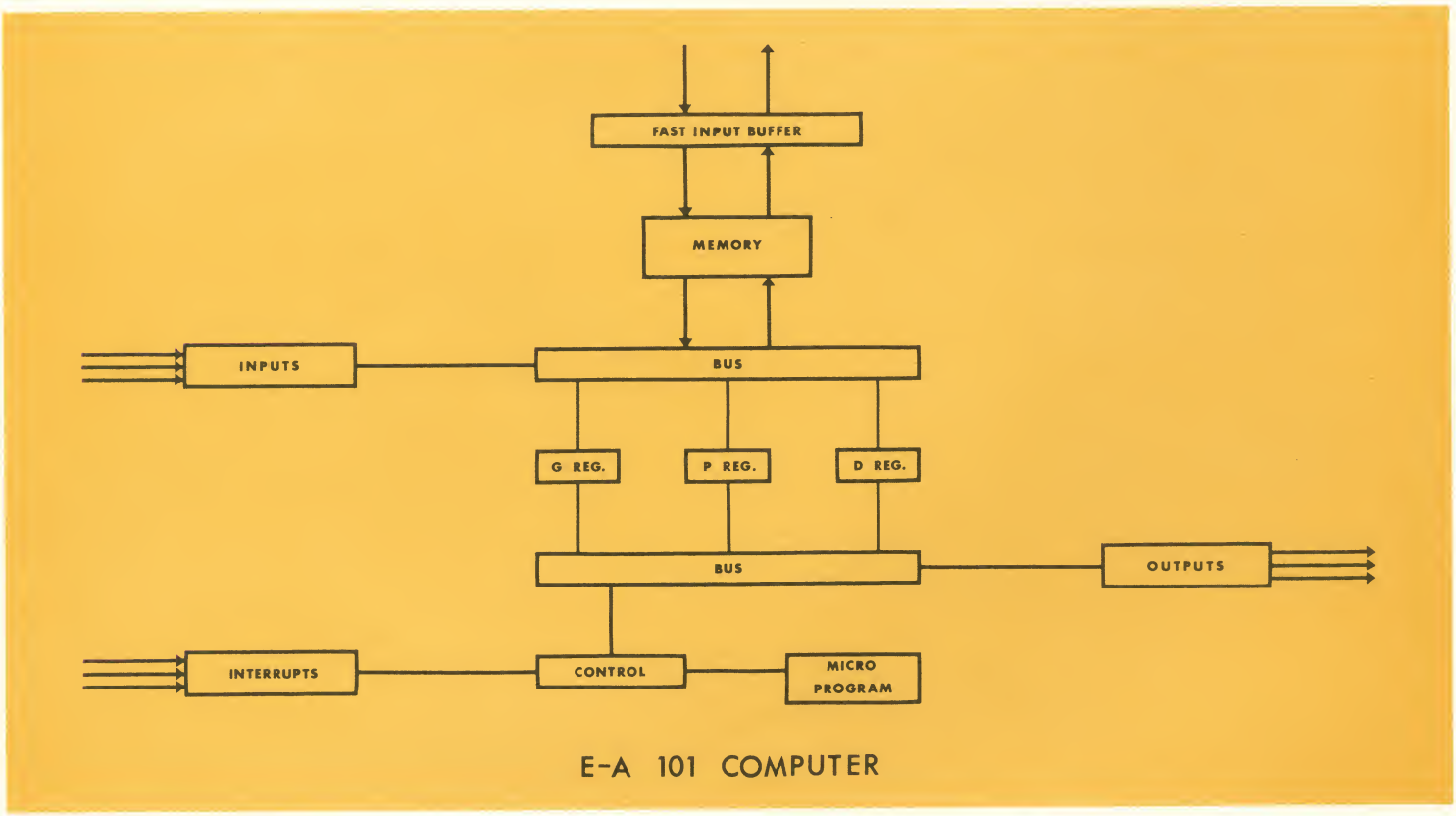
# ...EA 101 DIRECT DIGITAL CONTROLLER

## NEW STEP FORWARD IN INDUSTRIAL CONTROL




E-A 1000

COMPUTER CONTROL HIERARCHY




E-A 101 COMPUTER

## ...step-by-step control automation

# EAIC DESIGN PHILOSOPHY

Years ago, the advent of on-line, realtime industrial control was envisioned as one of the great promises inherent in automation technology. Today automatic control has fully come of age as an operating reality in hundreds of power plants, petrochemical refineries, glass, paper and steel mills, natural gas and other processing installations throughout the world.

Perhaps the most dramatic forward step came with the application of direct digital control in closed loop design. Simply by eliminating unessential analog links, total systems control simultaneously became faster, less expensive, more reliable and less error prone. Ample field testing and accumulated documentation show that direct digital control does indeed allow faster recovery from disturbance, gentler and more positive control, and greatly improved operator supervision.

Yet even as technical sophistication continued to advance into the 1960's, many of the early experiments in automatic control were beset with unforeseen difficulties. From top management came increasing concern that some hardware costs were out of proportion to resulting increases in profitability; that process control engineering frequently gave evidence of excessive hardware capacity and unneeded performance; that too many control computer systems had been inefficiently designed for long-range growth and expansion.

For equipment manufacturers, the lesson was clear: more attention to the managerial objectives of economic justification, equipment compatibility and overall systems performance.

For all of these considerations, EAIC decided upon an equipment design philosophy which corresponds to a proven principle of business organization: management-by-exception hierarchy of control. In essence, this means that the more repetitive or recursive functions are delegated to lower level decision centers. Exception situations and policy parameters are determined at higher levels of command. Implemented in operational hardware, the highest managerial level is represented by the EA 4100; middle management control by the EA 9000; supervisory level of control by the EA 101.

Any combination of EA 4100, EA 9000, and EA 101 may be suitably interconnected to form the EA 1000 system hierarchy.

EAIC's hierarchy of hardware control provides a number of significant advantages for management. First, it offers earlier return upon equipment investment, lower risk with the initial decision to automate, and a suitable plan for gradual growth and expansion.

Second, value engineering provides more performance per dollar. The EA 1000 system is precisely tailored to application needs by adding or subtracting "building blocks" as needed, making the most of all systems, subsystems, and components right down to the last wire. This provides a timely answer to mismatched capacity, eliminating idle circuits which are "loafing on the job" beneath their metallic housing.

Third, a hierarchial structure has more intrinsic safety and reliability. At higher levels, decisions are required less frequently than at lower levels. Therefore, disability of a computer at higher levels has less influence on the operational downtime of the system. In contrast, more dependence exists on the lower levels because their functions are continuous and on-line. The simplicity of EA 101 Direct Digital Control adds greater reliability where it is needed most. More complex control circuitry is deferred to the compatible EA 9000 and EA 4100.

The purpose of this booklet is to describe how the EA 101, in addition to its role in step-by-step automation, serves as a completely autonomous control computer.

## THE EA 101 DIRECT DIGITAL CONTROL

The low-cost EA 101 is specifically designed to provide the fastest possible return on investment. Although competitive with conventional instrumentation in price, the 101 provides a completely autonomous system for up to 100 loops per second with time to spare for necessary computation and control.

The system may also be expanded as needed, providing a risk-free approach to automation step by step. Speed, programming and componentry are all tailored to the needs of the application; excessive reserve capacity and command sophistication are purposely deferred to more relevant higher levels of logical control and computation as needed.

Streamlined man-machine communications and microprogramming account for considerable savings in machine programming, set-up and operations, a combination of factors which normally are responsible for more expense than hardware itself in complex systems.

### High Reliability Controls and Alarms

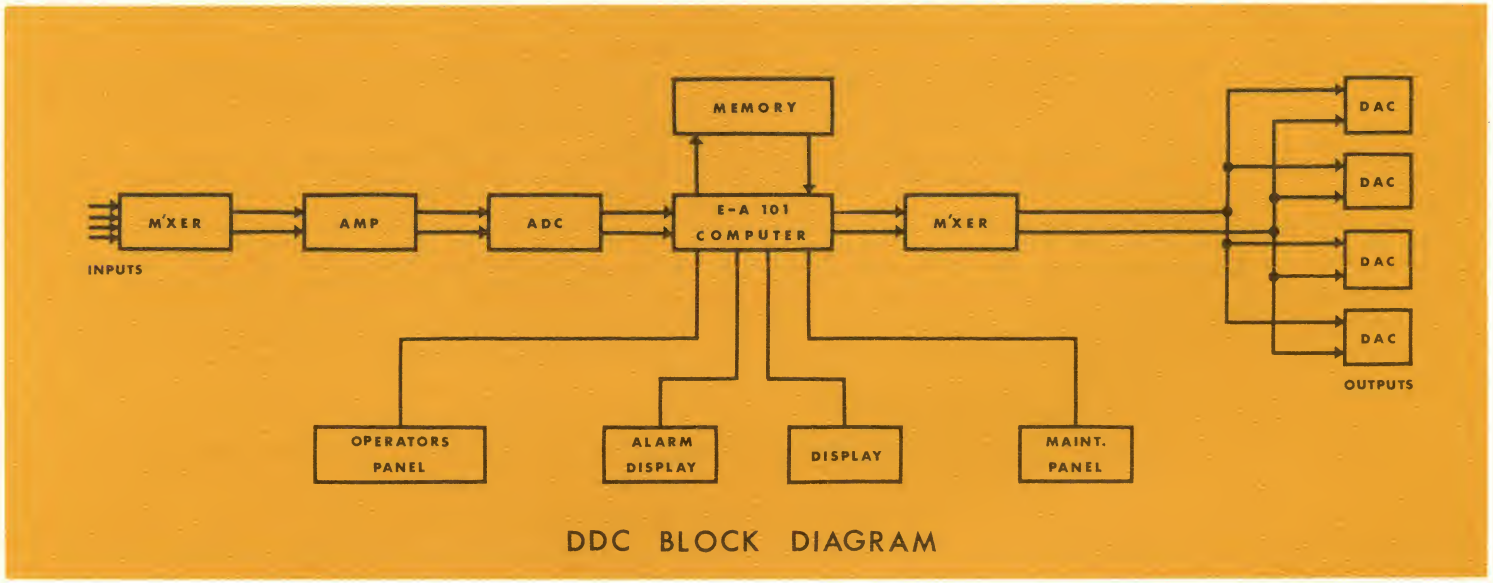
High-low alarm limits on every variable are preadjusted via the 101 control console. Whenever input exceeds either high or low condition, the audible alarm is triggered; the visual display goes red and switches to the out-of-tolerance loop number. Both audible and visual alarms continue until the operator presses the ACKNOWLEDGE button.

## SYSTEM IN OPERATION

Standard flow of information through the control loop includes analog measurement, conversion to digital form, check for alarm condition, setpoint comparison, error integration, addition of reset and proportional signals, self-check for reasonableness of command, and finally direct digital adjustment of the process under control.

Inputs to the EA 101 may come from any of the conventional instrumentation transducers; e.g., thermocouples, resistance thermometers, transmitters, and others. After being selected by a multiplexer and amplified through the differential amplifier, these inputs are then converted by A-to-D into a 12 bit binary number for processing.

This 12 bit word — actually the process measurement —is then worked through the 101's algorithmic program to produce the necessary output signals. These are then sent directly to close a contact switch, position an actuator, or make any other necessary adjustment.



DDC BLOCK DIAGRAM

This direct digital control by the EA 101 has proved to be a more reliable, less costly, faster and more sensitive approach to control economics. In addition to eliminating unnecessary analog links, all redundant circuitry and complex command componentry have been *designed out* of the system.

## BUMPLESS OPERATION AND EQUIPMENT SAFEGUARDS

The EA 101 is designed for total system performance under all conditions, including emergencies and crisis situations which may arise. Output commands, for example, are always submitted to a "reasonableness" check to insure that out-of-tolerance values can not possibly be communicated to the control instrumentation.

In case of power failure or computer malfunction, provisions are designed into the EA 101 to keep the

loop closed. This is accomplished with either the last value retained by A-to-D converters; or another output value which the operator may elect to insert.

At the same time, memory storage is not affected by computer shutdown. Non-destructible magnetic core storage and other design safeguards provide faster and more efficient start-ups.

All controls are easy to interpret and full access is provided to system inputs, outputs and computational functions. Or the operator may bypass computer control altogether with manual adjustments from the control panel.

## Convenient Man-Machine Communications

To assure ease of operator input, all data is entered in decimal form from the display panel. A translation routine within the machine converts into binary for internal operations. Similarly, all output data is retranslated into alpha-numeric form for maximum ease in visual display interpretation.

## Logical Control and Programming

EA 101 programming is tailored to application need and may be altered according to user specifications.

### MAXIMUM PROGRAMMING AND OPERATING SIMPLICITY

#### Typical 101 Microprogram Sequence:

1. Analog Variable → ADC = + V

2. $V \geqslant HI$ = HI ALARM
   $V < HI$ = NORMAL OR RETURN TO NORMAL

3. $LO \geqslant V$ = LO ALARM
   $LO < V$ = NORMAL OR RETURN TO NORMAL

4. SET POINT − V = ± E DEVIATION

5. (Positional) and/or (Velocity)

$$K_p E + K_R \Sigma E + K_I = C \qquad \frac{K_p}{\Delta t}(E_n - E_{n-1}) + K_p E_n = C$$

Where

$K_p$ = PROPORTIONAL BAND GAIN

$K_R$ = RESET RATE GAIN

$K_I$ = PROPORTIONAL CONSTANT OR MID-RANGE CONSTANT

C = INTERMEDIATE OUTPUT

$\Delta t$ = SAMPLING INTERVAL

n = LAST SAMPLE OBTAINED

n − 1 = NEXT TO LAST SAMPLE OBTAINED

$T = \frac{K_p}{K_R}$ = RESET CONTROL CONSTANT

C = INTERMEDIATE OUTPUT

6. $HI_2 \leqslant C \leqslant LO_2$ →
   1) Inhibit C entering Output and maintain previous DAC value
   2) Indicate Output alarm
   3) Maintain last set point value of next loop if Cascade marker exists.

   $HI_2 > C > LO_2$
   1) Output C to DAC
   2) Output C to Set Point of next loop if Cascade marker exists.

**The above program execution is for a typical algorithm. Other algorithms and equations may be programmed into the machine according to the individual application needs.**

Although the 101 is adaptable to nearly every major industrial control environment, programming and operational requirements are absolutely minimal. The machine does most of its own housekeeping and interpretation normally associated with programming. Displays and information readout are designed especially to facilitate user convenience and understandability.

Controller tuning and program alterations require no special machine languages, codes or operating procedures. Without any computer training, for example, an operator can change his integral values or any other loop coefficients as desired. Both input and output, including ERROR displays, are in decimal form.

Tuning of the loop parameters in the EA 101 is non-interacting, finer in discrimination, and wider in range. Control response of the overall process is therefore considerably smoother, faster and more sensitive. Dynamic control is also feasible.

The four main routines include computation; translation; input and output routines. Selected programs and routines are implemented by modular circuit boards. These may be augmented or modified as needed to provide maximum performance per dollar.

PROGRAMMERS NOTE: Basic scanning cycle is 100 loops. With fewer loops, the scanning rate can be increased by examining each loop more than once per cycle. Proportional band is adjustable from 1,000 percent to 0.1 percent; and reset rate from 1 to 0.0001 repeats per second. Large registers allow a computing accuracy of 24 bits, plus sign; all loop parameters can be resolved to 1 part in 10,000. Cascading is available between any and all variable points. Each point can be eliminated.

## EA 101 MEMORY STORAGE

The non-destructible magnetic core memory is always protected in the event of computer downtime or power failure. During operation, ample storage is provided for coefficients of the algorithm, program markers, and intermediate information to be processed or cascaded forward.

Data may be read into memory either from the operator's console or from the communications channel of another on-line computer.

## EA 101 OUTPUT SIGNALS

The EA 101 control output signals may take three forms.

1. An analog dc current to suit the conventional valve actuator. These have ranges of 1-5 ma, 4-20 ma and 10-50 ma.
2. A train of pulses to drive stepping motor-type digital transducers.
3. Contact closures.

## EA 101 OPERATOR CONTROLS

- HI and LO limits entry and display
- Set point entry and display
- Loop coefficients entry and display
- Measured value and deviation display
- Audible alarm signal
- Visual alarm signal
- ACKNOWLEDGE button
- Computer bypass control
- Manual adjustment of actuators
- Machine-to-machine interface for intercommunications between other computer systems
- Optional data logging controls.

Common language communications between the operator and machine are designed for maximum ease in man-machine interactions. Operator control facilities include loop parameters, alarms, settings, deviations, operations, computer bypass and manual adjustments.

## DESIGN FEATURES

Design organization, components and materials in the EA 101 system have been carefully selected for an optimum mix of cost and operating performance: minimal number of parts (as few as 24 circuits), silicon semiconductors, glass epoxy printed circuit cards, and bifurcated spring type connectors. Interconnections between cards are made by means of wire-wrapped joints. Input switches are mercury-wetted; storage elements are magnetic core.

## EA 101 OPERATING CHARACTERISTICS

- PROPORTIONAL PLUS INTEGRAL CONTROL
- FIXED RATIO CONTROL BY MANUAL SETTING OR VARIABLE RATIO CONTROL DETERMINED BY COMPUTATION OF A CASCADED FUNCTION
- MICROPROGRAMMED POSITION AND/OR VELOCITY ALGORITHMS
- INDIVIDUAL HI AND LO LIMIT CHECKS FOR EACH LOOP
- DOUBLE PRECISION COMPUTATION (25 bits)
- CASCADING FROM ONE LOOP TO ANOTHER UNDER PROGRAM CONTROL
- NO RESET WIND-UP
- INDIVIDUAL POINT ELIMINATE IN EVENT OF TRANSDUCER MALFUNCTION
- PRIORITY INTERRUPT FROM EXTERNAL STIMULI
- ALPHANUMERIC/ENGLISH LANGUAGE OPERATOR-MACHINE COMMUNICATIONS
- OPTIMUM INTERFACING WITH ANY OTHER COMPUTER
- FLEXIBLE TIE-IN WITH EXISTING PLANT INSTRUMENTATION
- SYSTEM SELF-CHECK AND OUTPUT CHECK FOR REASONABLENESS
- PROVISIONS FOR MANUAL CONTROL IN EVENT OF SHUTDOWN

## EA 101 EQUIPMENT CHARACTERISTICS

- MAGNETIC CORE MEMORY
- INFORMATION STORAGE SAFEGUARDS IN EVENT OF POWER FAILURE
- ALL SILICON COMPONENTS
- WIDE OPERATING MARGINS
- 0° to 50° C. TEMPERATURE RANGE
- HIGH NOISE IMMUNITY CIRCUIT DESIGN
- MODULAR SYSTEM EXPANDABLE IN SINGLE CHANNEL INCREMENTS
- MERCURY-WETTED INPUT SWITCHING
- OPTIONAL BATTERY SYSTEM
- OPTIONAL DATA LOGGING

EA 101

Marketing offices for EAIC are located in major cities throughout the United States. For more information concerning the E-A hierarchy of control systems, call the representative nearest you. Or contact the West Coast manufacturing center for EAIC computer systems: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